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ELECTRONIC BORE MEASURING SYSTEM

Vito G. Compisi, et al

Watervliet Arsenal
Watervliet, New York

September 1972

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ELECTRONIC BORE MEASURING SYSTEM

TECHNICAL REPORT

SEPTEMBER 1972

QUALITY ASSURANCE DIRECTORATE

U.S. ARMY WEAPONS COMMAND
WATERVLIET ARSENAL
WATERVLIET—NEW YORK

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GEORGE W. JACQUES

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13. ABSTRACT

The design, construction and testing of a universal electronic measuring instrument is described.

The instrument features expanding parallel arms with contact shoes and electronic probes through which the transmitted measuring signals are read as a digital display. This instrument provides for a single measuring head that will replace the present Star gage measuring heads and their related components. Results of measurements on digital display, resolution, accuracy, repeatability and stability are presented.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Star Gages						
Bore Erosion						
Electronic Gaging Cartridge						
Digital Readout Unit						
Linear Variable Differential Transformer						
Simultaneous Diameter Dimension Display						

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ACKNOWLEDGEMENT

The authors wish to gratefully acknowledge Mr. J. Fiscella for his advice and direction in this project. Also, the technical assistance contributed by Mr. P. Graney in the calibration and testing of the equipment.

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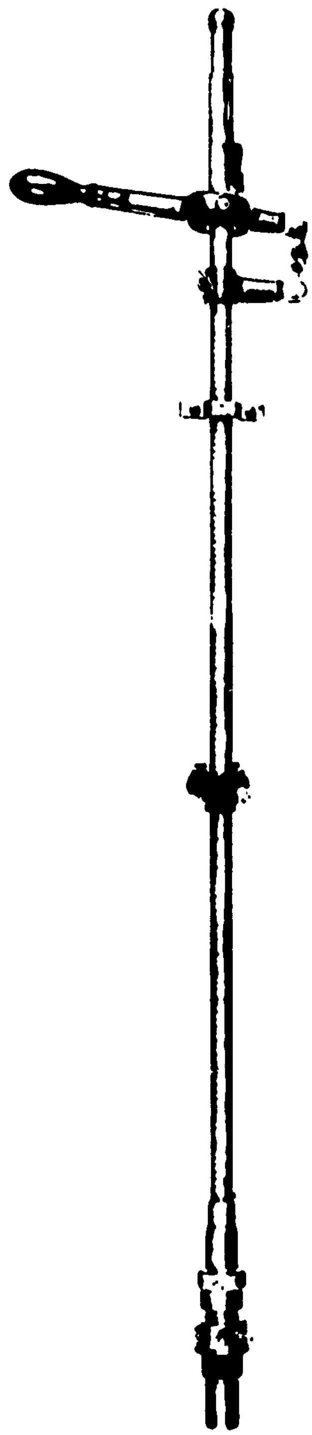

FIGURE 1. LEVER-TYPE STAP GAGE

1. INTRODUCTION.

The application of Star gages to measure bore diameters is well known. They are chiefly used to measure the normal or abnormal wear and erosion of bores and chambers of cannon to determine their remaining accuracy life. They also measure pitted areas which occasionally form in the bore of a cannon. Star gages are used during the manufacture of cannons to determine the interior diameters of ordnance parts such as tubes, jackets, hoops, liners, etc. They may also be used to measure the inside diameter of recoil cylinders, recuperator cylinders and other objects of circular bore.

The objective of the work reported here was to design, build and test a portable measuring system capable of better resolution and greater accuracy. Additional requirements were ease and simplicity of operation, minimal size and weight, repeatability and stability.

a. Present Measuring System. The system presently used to measure bore diameters is the lever-type Star gage. This gage is the standard for use in the field, at base arsenals and at manufacturing plants. (See Figures 1 & 2). The Star gage basically consists of the Tube, Rod, Head, Wedge, Carriers, Lever, Slide, Points and Sleeve. (See Figure 2).

b. Functioning. A section view of a typical lever-type Star gage is shown in Figure 2. The TUBE, a long hollow staff, houses a square operating ROD and carries a HEAD at its forward end. The HEAD partially houses a WEDGE connected to the operating ROD and has transverse slots for each measuring point CARRIER. The carriers are supported on the WEDGE by T-shaped slots which engage the T-shaped flutes of the WEDGE. The operating LEVER is mounted at the rear end of the TUBE. The LEVER is trunnioned to a SLIDE which is attached to the square operating ROD. The LEVER and SLIDE have a sliding motion on the end of the TUBE and the movement of the LEVER is communicated through the operating ROD to the WEDGE. Movement of the WEDGE, forward or backward, causes a corresponding movement of each measuring POINT, out or in, to contact or retract from the cannon bore diameters. A vernier scale comprised of the vernier sleeve located on the sleeve and the flat vernier which is screwed to the SLIDE is calibrated relative to the known taper of the WEDGE. The vernier scale is graduated to indicate variations in the diameter of the cannon bore being measured from the normal diameter or caliber of the cannon.

2. SYSTEM DESIGN AND CONSTRUCTION.

The major limitations for the present work, were the size of the measuring head, stability of the expanding arms, the mounting of the

electronic gaging cartridges and the resolution and accuracy of the system. In order to meet these requirements for the new system, it was decided to use high quality steel for the expanding arms and transfer shoes; and electronic cartridges which have exceptionally light and uniform gaging pressure. This feature permits leeway in the length of the holding lug without running into inaccuracies due to deflection and lost motion. The associated equipment for the electronic cartridges consists of a precision 5 digit digital readout instrument and an electronic amplifier completely transistorized. This provided the accuracy and resolution required for this system.

3. SYSTEM DESCRIPTION.

The Electronic Bore Measuring System basically consists of an adjustable plug type head assembly in which are housed four linear variable differential transformers (LVDT), two amplifiers, two digital readout consoles, extension tubes and setting master. The measuring system is shown schematically in Figure 3 and actually in Figures 4 & 5.

The instrument is calibrated using the instructions supplied for the amplifiers and digital readout units. The instrument is then set to the setting master which simulates the conditions of actual size and use, including the method of application. (See Figure 4).

Figure 6 shows the application of the measuring head in a portion of a 152 M/M tube. The readings obtained are shown on the digital readout and/or amplifier meter. On the dual input amplifiers, a Polarity Switch is provided for each gaging cartridge. When the Cartridge Selector Switch, "F" in Figure 7 is in the "Both" position, and the Polarity Switches "B" are in like positions (both "Normal" or both "REV") the amplifier responds to the sum of the opposite polarities and thus, in effect, subtracts one output from the other, producing a differential reading, Figure 8.

Basically, two LVDTs are used to measure the bore diameter (one each on radius) and two to measure the rifling diameter (one each on radius). The LVDTs are connected to the differential amplifiers and provides a direct reading of each LVDT for the diameter checks. The amplifiers are connected to the digital readout which displays the actual readings.

In operation, the head assembly is passed through the cannon tube; the bore and rifling diameters are displayed simultaneously at any point along the length of the cannon tube. Total Instrument Reading (TIR) between bore and rifling diameters is obtained by measuring the depth of the two rifling grooves diametrically opposed. The two LVDTs connected to the differential amplifier provide the direct reading for this check by putting the Polarity Switches in

unlike positions (one "Normal" and one "REV"). Repeatability within .0002-inch is assured because of the construction and locking method of the measuring head.

4. TEST RESULTS AND EVALUATION.

a. The testing and evaluation of the Electronic Bore Measuring System versus the Star gage system consisted mainly of measurements made within a 152 M/M cannon tube. The equipment used included the above systems and their master setting rings. The master setting rings were checked and certified to be correct to the basic bore and rifling diameter size of the 152 M/M tube by the Watervliet Arsenal Metrology Laboratory Division. Their accuracy was established by using gage blocks which were compared with master blocks to an accuracy of a few millionths of an inch.

b. The repeatability of the systems was based on the following method of testing:

1. The zero settings for the measuring systems were established by applying the master setting rings.

2. A stop was placed at the end of the tube and 72 readings were taken at the same location with both measuring systems.

c. The Frequency Distribution Tables (Figures 9 & 10) depict the 72 readings. The Frequency Distribution Charts (Figures 11 & 12) are based on sigma limit (standard deviations). The charts show

the standard deviations and sigma limit of the readings for the Electronic Bore Measuring Head and the Star gage. Note: The difference in the spread of the distribution charts - .0004-inch versus .003-inch. This is based on the actual resolution inherent in the two systems — .0001-inch for the Electronic Bore Measuring System versus .001-inch for the Star gage.

d. Figure 11 (Electronic Head) shows that 68.2% of all readings from a large number of samples will fall within .00008-inch, 95.4% within .00016-inch and 99.7% within .0002-inch. Figure 12 (Star gage) shows that 68.2% of all readings from a large number of samples will fall within .0005-inch, 95.4% within .001-inch and 99.7% within .0015-inch.

e. The repeatability of the Star gage measurements were dependent on the operator's "feel" of the instrument. Variations in vernier readings can result from different pressures being exerted on the expanding points and from parallax in reading the vernier scale. The repeatability of the Electronic Bore Measuring System did not require "feel", but obtained the actual readings through the light gaging pressures of the electronic probes and the readings which were digitally displayed.

f. These measurements made within the 152 M/M cannon tube have shown the following advantages of the Electronic Bore Measuring System over the present Star gage system.

1. The Electronic Bore Measuring System provides a flexible range of measurement for application on different size bores. (See Figures 13 & 14).

2. Provides increased accuracy and resolution - .0001-inch versus .001-inch on the Star gage.

3. Provides a simultaneous display of diameter dimensions in 3/4" highlighted numbers on the digital readout console versus reading one diameter at a time using the Vernier on the Star Gage.

4. Provides maximum rigidity and stability by applying unique and sound geometric principles of parallelogram construction.

5. Provides superior portability as well as decreased manufacturing and maintenance costs.

g. Evaluation of the Electronic Bore Measuring System shows that the substitution of this system for the Star gage presently used will greatly improve efficiency in the inspection of cannon tube bores. In direct comparison with the Star gage, the Electronic Bore Measuring System eliminates eye-fatigue on the part of the inspector as well as disagreements due to differences between individuals in applying correct "feel" in expanding the points of the Star gage to the diameter of the bore.

5. CONCLUSIONS.

The currently used Star gage method of inspection of cannon bore diameters, although adequate, causes operator fatigue and increases the probability of human error in vernier readings.

The Electronic Bore Measuring System requires less time for set-up and calibration. Accuracy and repeatability are improved with electronic equipment. The ability to obtain direct readings for concentricity without additional mathematical computation insures more reliable measurements and reduces inspection time.

6. RECOMMENDATIONS.

Since the results of the performance evaluation between the two instruments are favorable for continued development efforts on the Electronic Bore Measuring System, it is recommended that studies and work be continued on design refinement and the preparation of product engineered drawings for the acquisition of measuring systems.

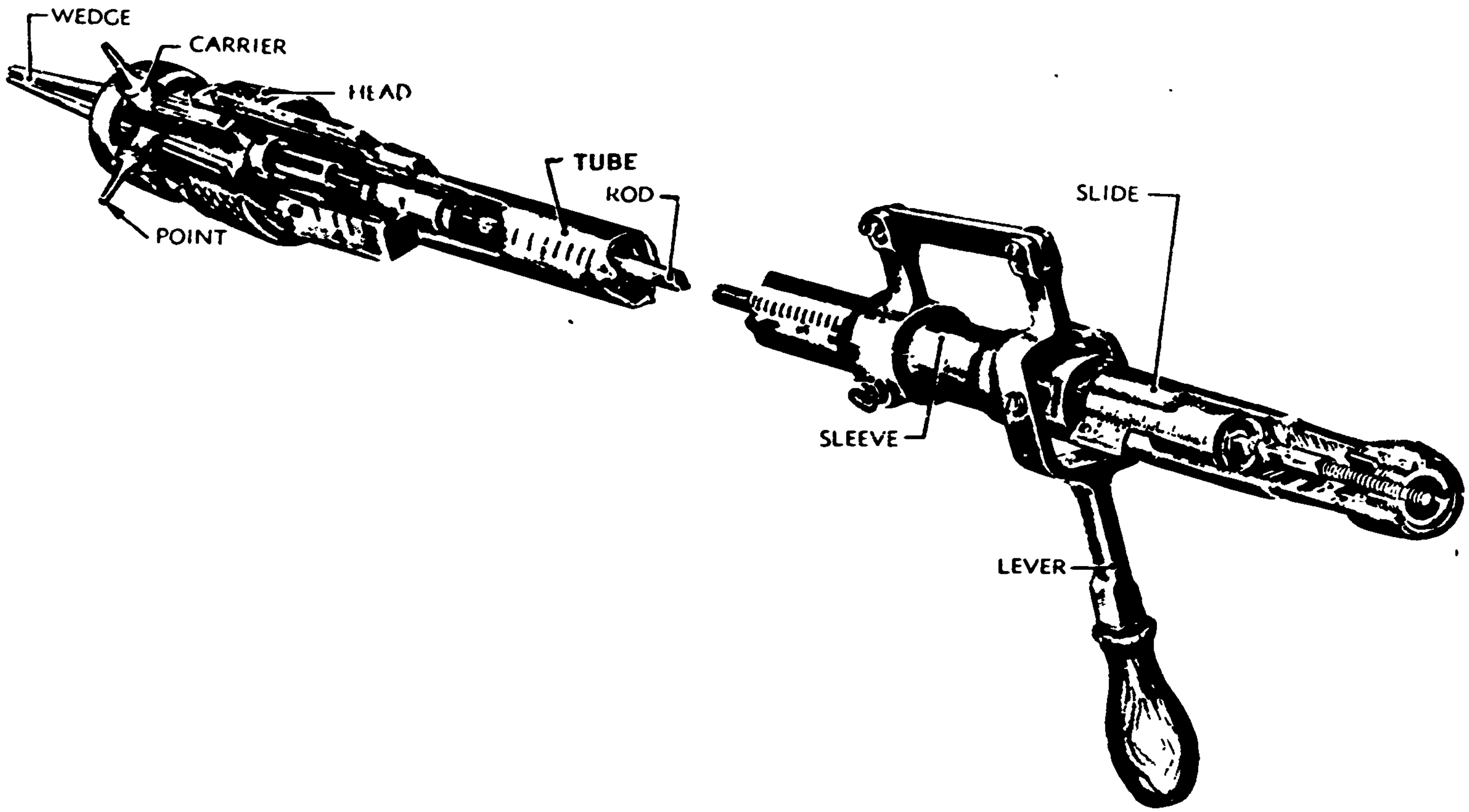

FIGURE 2. SECTION VIEW OF TYPICAL STAP GAGE

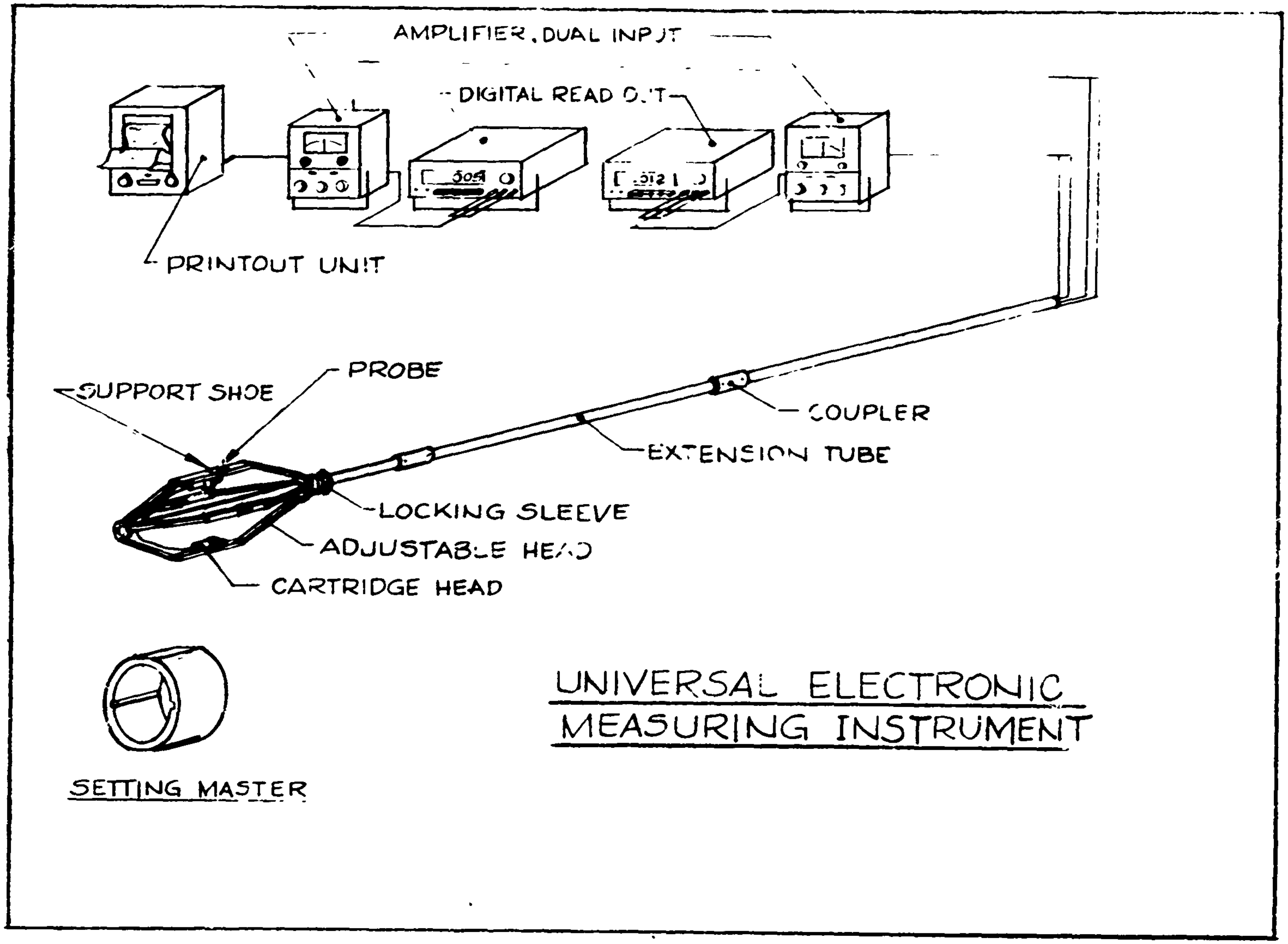

FIGURE 3. SCHEMATIC VIEW OF ELECTRONIC MEASURING SYSTEM

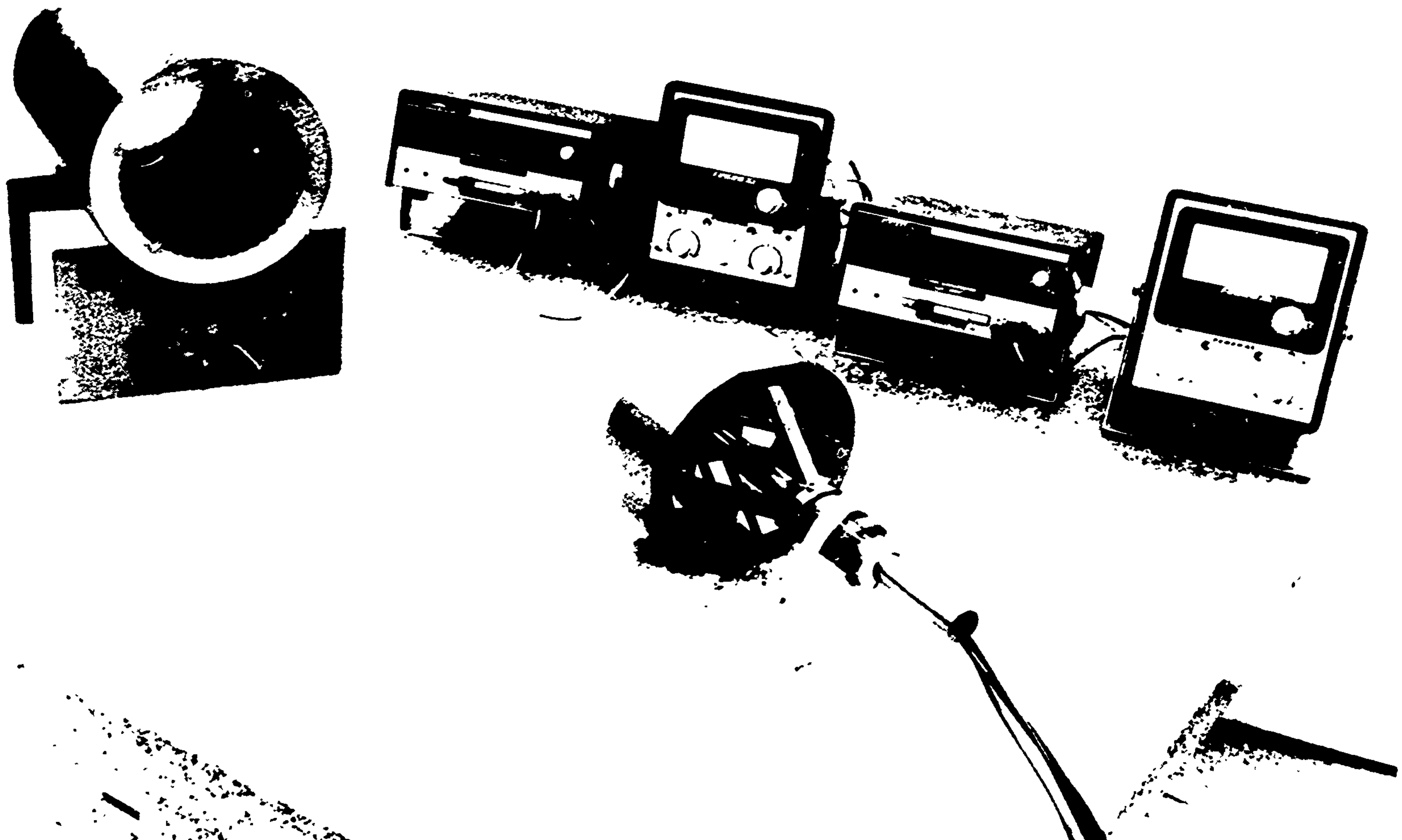

FIGURE 4. APPLICATION OF MEASURING HEAD TO SETTING MASTER

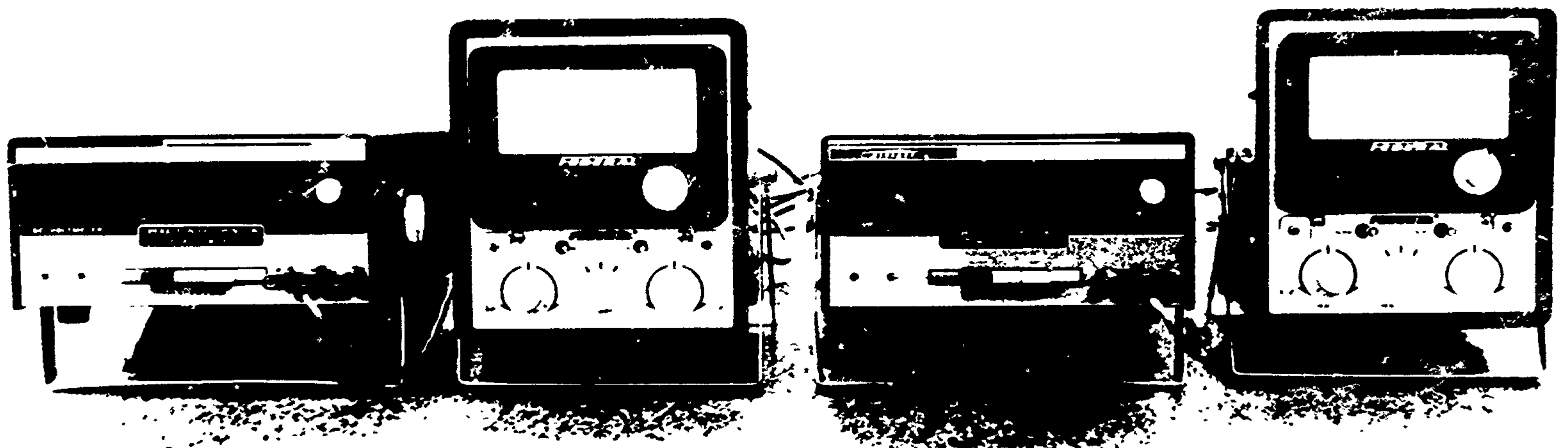

FIGURE 5. AMPLIFIERS AND DIGITAL READOUT UNITS

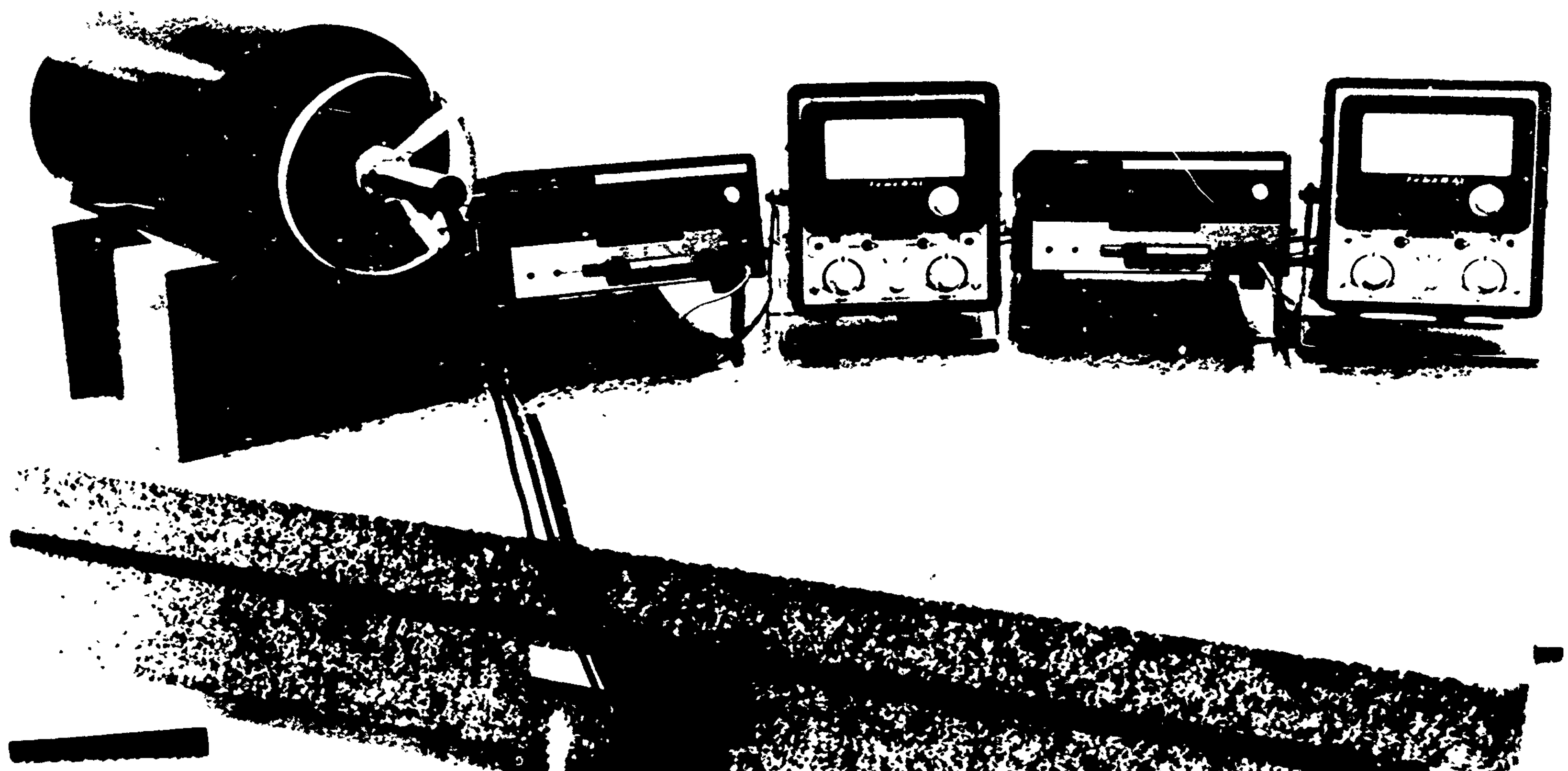

FIGURE 6. APPLICATION OF MEASURING HEAD TO PORTION OF 152 M/M TUBE

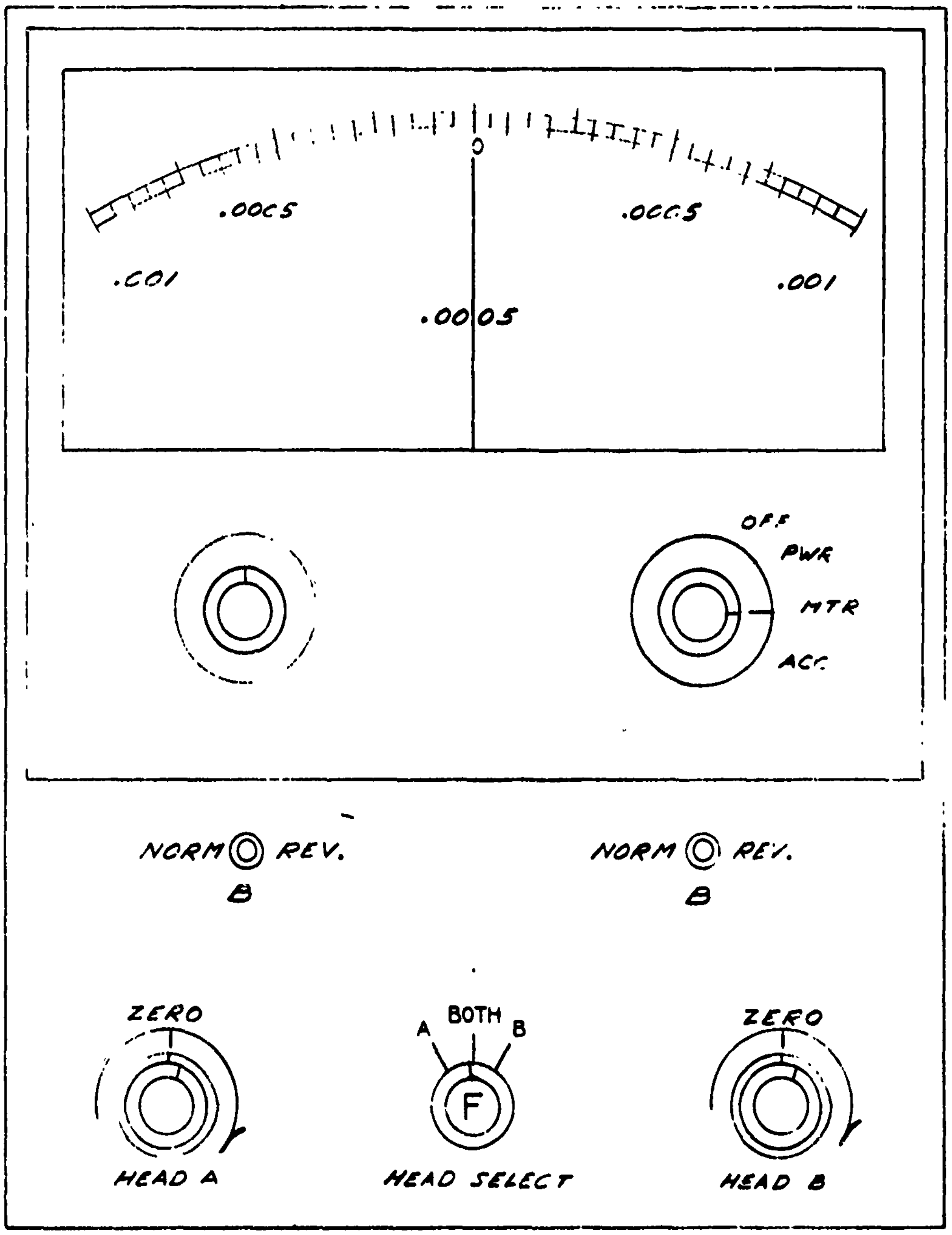

FIGURE 7. DIFFERENTIAL READING PRODUCED ON AMPLIFIER BY THE USE OF POLARITY SWITCHES

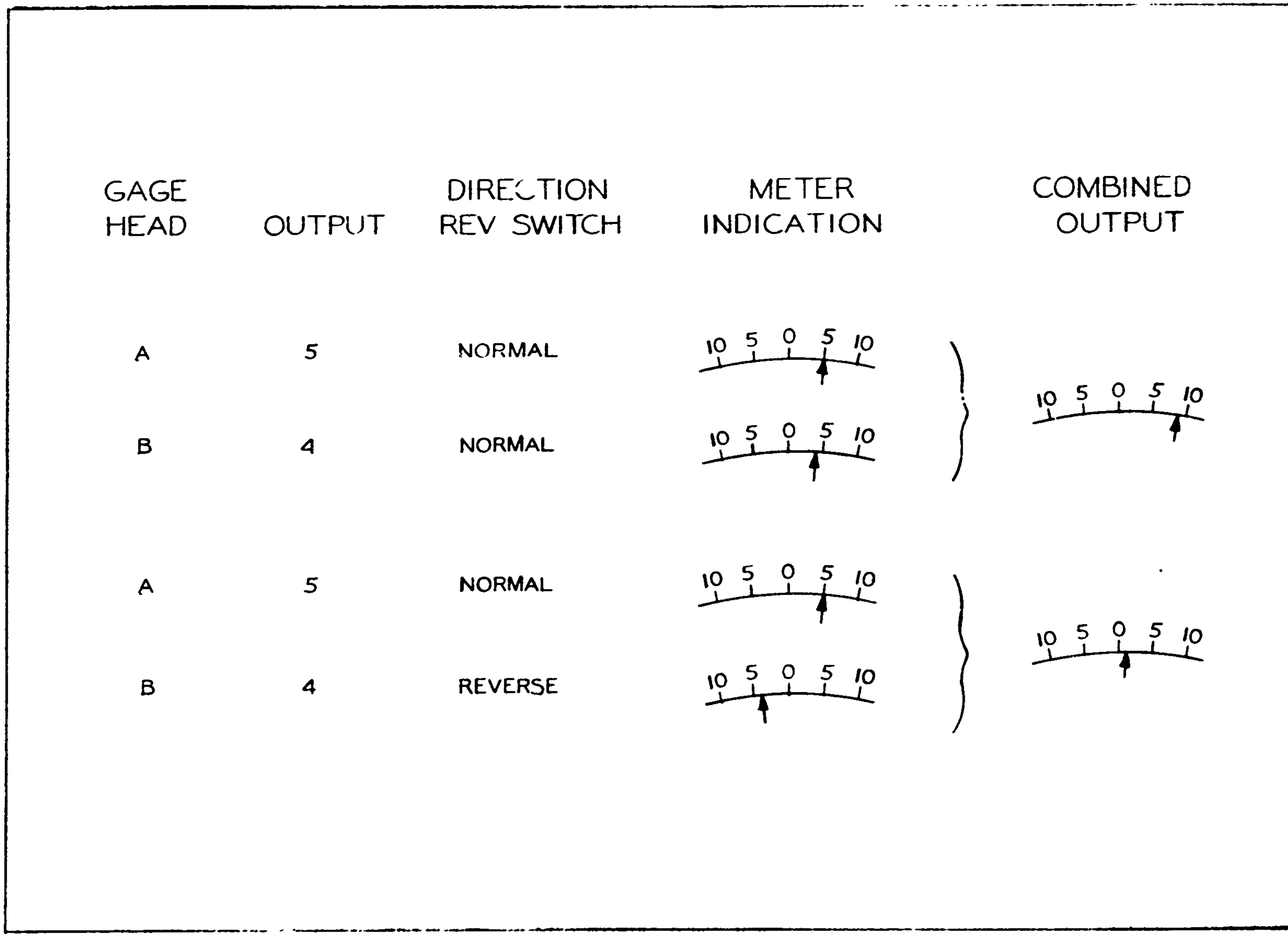

FIGURE 8. AMPLIFIER SETTINGS

FREQUENCY DISTRIBUTION STUDY OF
THE ELECTRONIC HEAD

Reading In Inches	Frequency
+.00020	1
+.00016	4
+.00012	4
+.00008	9
+.00004	14
0	10
-.00004	15
-.00008	5
-.00012	4
-.00016	4
-.00020	2

FIGURE 9. FREQUENCY DISTRIBUTION TABLE

FREQUENCY DISTRIBUTION STUDY OF
THE STAR GAGE

Reading In Inches	Frequency
+.0015	2
+.0010	11
+.0005	16
0	19
-.0005	14
-.0010	9
-.0015	1

FIGURE 10. FREQUENCY DISTRIBUTION TABLE

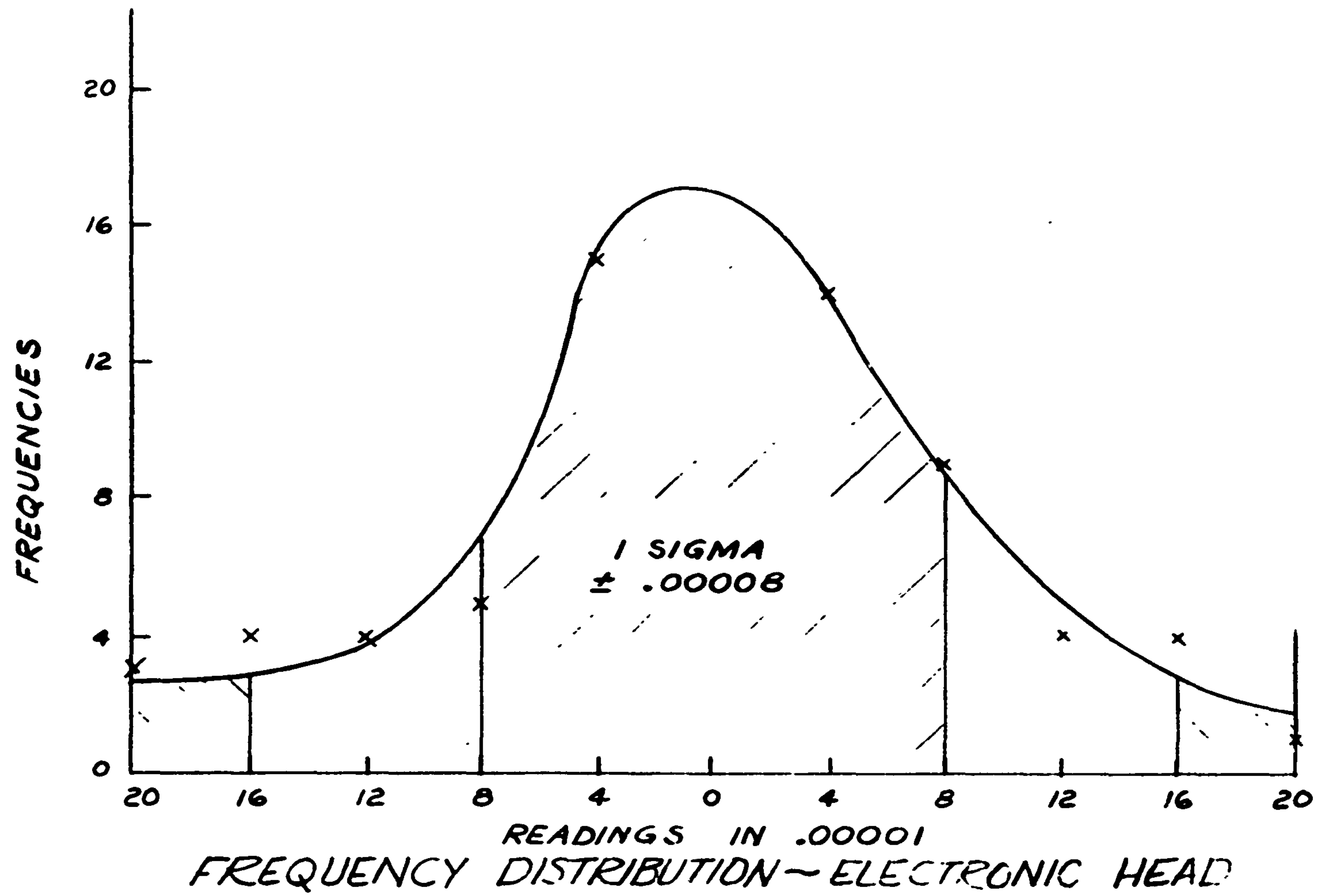

FIGURE 11. FREQUENCY DISTRIBUTION CHART

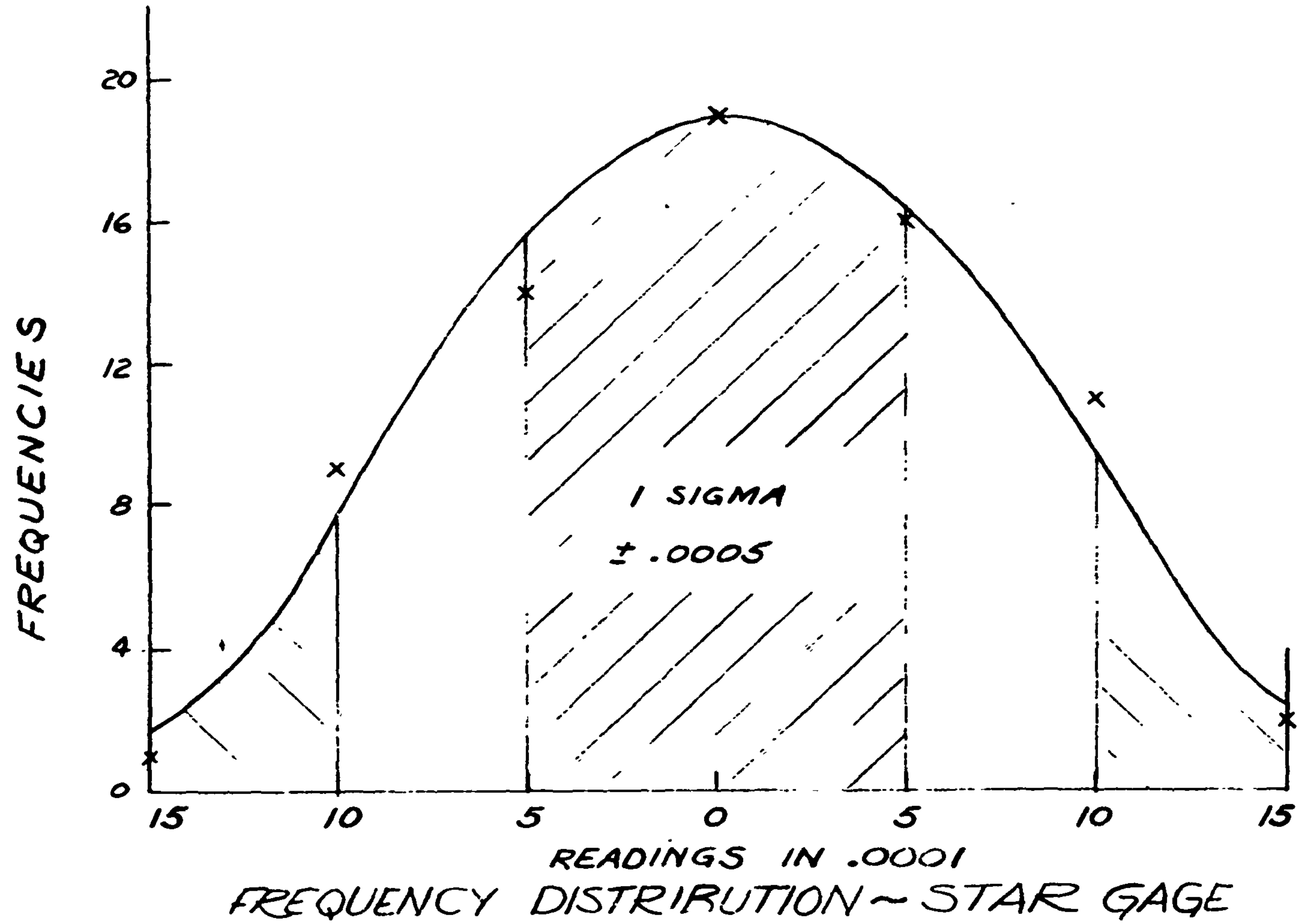

FIGURE 12. FREQUENCY DISTRIBUTION CHART

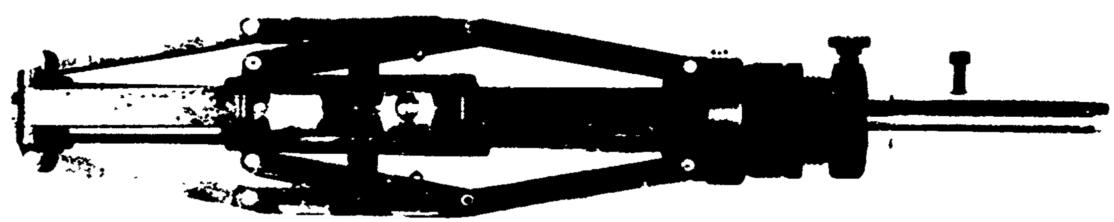

FIGURE 13. MEASURING HEAD RETRACTED TO 90 M/M DIAMETER

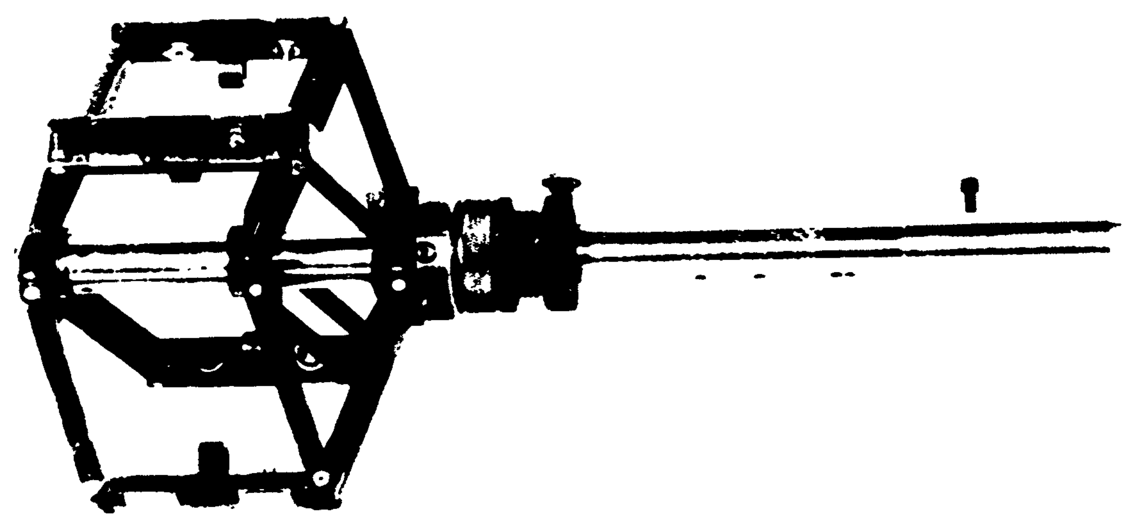

FIGURE 14. MEASURING HEAD EXPANDED TO 8-INCH DIAMETER